Nd-YAG Laser Treatment of Tracheal Stenosis

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We administered Nd-YAG laser treatments in four patients aged 56 to 68 years for severe tracheal stenosis, the tracheal diameters varying between 2.5 and 5 mm. These patients were all dyspneic at rest with talking or dressing and their peak flows ranged from 8% to 36% of predicted. They were not felt to be candidates for surgical excision. Immediate palliative relief was achieved in all patients and lasted two to four months after a single treatment in three patients. One patient died three weeks after laser treatment due to respiratory failure from underlying emphysema. There were no complications of laser therapy. Postlaser therapy the tracheal diameter in each patient was at least 9 mm and peak flow improved to between 25% and 76% of predicted. The results suggest that laser treatment may be beneficial in cases of severe tracheal stenosis.

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Society today is placing greater emphasis on justifying monetary expenditures in health care delivery, especially with new technologies. In this article we address the issue of the clinical appropriateness of the neodymium-yttrium-aluminum-garnet (Nd-YAG) laser in the treatment of advanced nonmalignant tracheal stenosis when no other rational medical or surgical approach is feasible. Results indicate that Nd-YAG laser treatment may provide immediate and temporary palliative relief.

Materials and Methods

The Nd-YAG laser (Medilas, MBB, Endo-lase, Inc, Washington, DC) generates a timed output of up to 80 to 100 W in the infrared wavelength—1,064 nm—which is conducted by a flexible quartz monofilament. The techniques we used are similar to those previously reported.[1]

Our indications to administer the laser treatment included a partially obstructed trachea that has not responded to mechanical dilatation in patients with uncontrolled cough, stridor and unrelenting dyspnea. These patients were felt to be too dyspneic to undergo an attempt at surgical excision of the stenotic area. Detailed informed consent was obtained from each patient, consistent with guidelines from the manufacturer's specifications and the US Food and Drug Administration, the California Patient's Bill of Rights and the local hospital institutional review committee. Immediate palliative improvement was determined by enlargement or recannulation of a previously obstructed trachea with relief of dyspnea, cough and stridor and associated physiologic improvement.

Before laser therapy we measured the patient's Dyspnea Index[2] and modified it so that a Dyspnea Index of 1 is shortness of breath only on climbing stairs, 2 is inability to walk a mile on level land at a normal pace, 3 is shortness of breath on walking 100 yd on level land and 4 is shortness of breath with slight exertion after dressing or talking. Pulmonary function studies (WE Collins, Inc, Braintree, Mass) and maximal expiratory and inspiratory flow volume loops were measured before and one day after laser therapy and results compared with previously published standards.[3-7]

Results

The four patients who underwent laser surgical treatment were extremely dyspneic with cough and stridor at rest. In each patient tracheal stenosis developed as a result of endotracheal intubation or tracheostomy (or both) done 4 to 24 months previously for management of repeated episodes of respiratory failure due to emphysema (cases 1 and 4) or congestive heart failure (cases 2 and 3). The patient in case 1 required repeat endotracheal intubation and mechanical ventilation before the laser therapy. Results of the pulmonary function studies are given in Table 1 and indicate severe

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TABLE 1.—*Results of Routine Pulmonary Function Studies in Patients With Tracheal Stenosis**

			prelaser							*postlaser*				
								$\dot{V}_{50}$					$\dot{V}_{50}$	
Patient	*Sex*	*Age Years*	*D_LCO (ml/min/mm Hg)*	*TLC Liters*	*PF Liters/sec*	*FEV_1 Liters*	*FVC Liters*	*Insp Liters/sec*	*Exp Liters/sec*	*PF Liters/sec*	*FEV_1 Liters*	*FVC Liters*	*Insp Liters/sec*	*Exp Liters/sec*
1	♀	68	NA	NA	0.3 (0.08)†	0.2 (8)	1.2 (35)	0.8 (17)	0.1 (2)	1.0 (25)	0.3 (13)	1.3 (38)	1.2 (26)	0.4 (9)
2	♀	56	7 (37)	2.5 (50)	1.8 (36)	1.0 (47)	1.1 (34)	0.9 (19)	1.6 (34)	3.8 (76)	1.1 (52)	1.1 (34)	4.0 (85)	3.4 (72)
3	♂	68	25 (110)	5.0 (94)	1.7 (24)	1.4 (56)	2.7 (89)	0.7 (15)	1.7 (36)	4.9 (70)	2.3 (92)	2.7 (87)	2.3 (49)	3.0 (64)
4	♀	60	11 (65)	3.2 (83)	0.7 (13)	0.7 (58)	1.1 (48)	0.6 (13)	0.7 (15)	1.7 (34)	0.8 (65)	1.2 (50)	1.0 (21)	1.2 (26)

D_LCO = single breath diffusing capacity of lung, TLC = total lung capacity, PF = peak flow on forced expiration, FEV_1 = forced expiratory volume in 1 sec, FVC = forced vital capacity, $\dot{V}_{50}$ = maximal flow at 50% forced inspiration (Insp) or 50% forced expiration (Exp), NA = not available.

*Results before and one day after laser treatment.

†Percent predicted.

abnormalities. This is best noted in the maximal expiratory and inspiratory flow volume loops as shown in Figure 1. The pulmonary function studies in patient 1 show severe variable intrathoracic tracheal airflow limitation superimposed on severe emphysema. Patient 2 shows a severe inspiratory air flow plateau consistent with variable extrathoracic tracheal obstruction superimposed with congestive heart failure and diffuse pleural thickening. In case 3, there were as severe inspiratory and expiratory flow limiting plateaus, consistent with a variable extrathoracic tracheal obstruction in a patient with underlying congestive heart failure. Case 4 shows flow plateaus similar to those in case 3 in a patient with underlying emphysema. All of the patients were extremely dyspneic on just talking or dressing, consistent with a Dyspnea Index of 4.

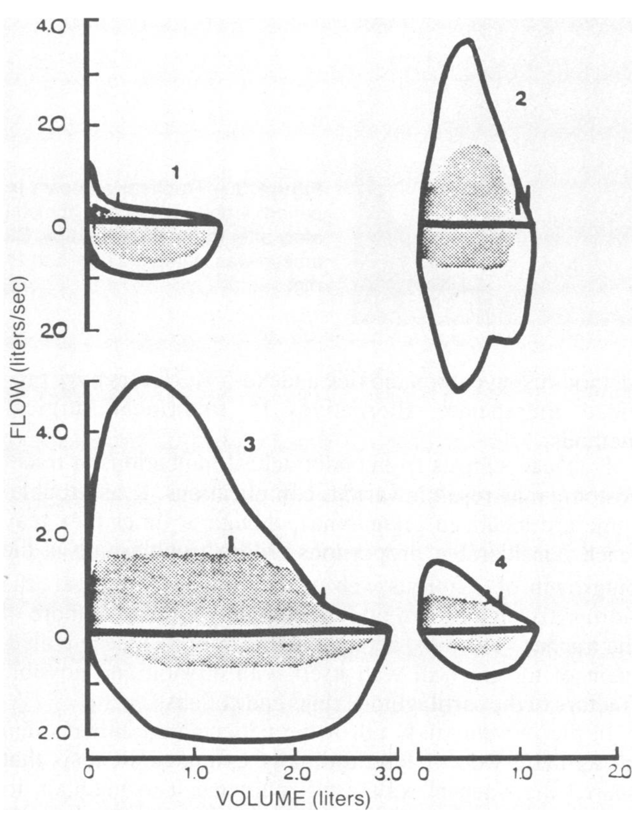

Figure 1.—Maximal flow volume loops on both expiration (above the horizontal 0 flow line) and inspiration in cases 1, 2, 3 and 4 before (shaded area) and one day after laser therapy. Age-corrected normal values[3] for 50% of expired forced vital capacity are 4.7 liters per second, ± 0.7 (mean ± 1 standard deviation) and for 25% of expired forced vital capacity 1.8 liters per second, ± 0.4. Values for inspiratory flow are similar. The slashed line on the expiratory loops mark off the forced expiratory volume in one second (see Table 1).

The location of the tracheal stenosis in patient 1 was a diaphragmatic web 2.5 cm below the vocal cords with a resulting tracheal diameter of 5 mm. The stenosis in patient 2 was 1.5 cm below the vocal cords and extended 1 cm inferiorly in a concentric manner with a tracheal diameter of 3.5 mm. In patient 3 the concentric stenosis began 2 cm below the vocal cords and extended 1.5 cm inferiorly with a tracheal diameter of 2.5 mm. Patient 4's stenosis began 3 cm below the vocal cords and extended 1 cm inferiorly with a tracheal diameter of 5 mm. This patient with severe emphysema had pronounced instability of the trachea and major airways.

After a single laser treatment the tracheal diameter in each patient increased to at least 9 mm (see Figures 2 and 3) with improvement in pulmonary function that may be best appreciated in the maximal expiratory and inspiratory flow volume loops (see Table 1 and Figure 1). Clinically the Dyspnea Index improved to 3 in patient 4 and to 2 in patients 2 and 3 and has persisted up to two to four months postoperatively after a single treatment. Patient 1's endotracheal tube was successfully removed but she subsequently died of recurrent respiratory failure three weeks after the laser therapy. Patient 2 required repeat laser therapy two months following the initial procedure, and similarly good results were achieved. There were no complications associated with the laser procedure.

The operative procedure and related overnight hospital and physician costs are estimated at $3,000 per laser treatment. For comparison, the average cost for a one-day hospital stay in the greater Los Angeles area is $1,000.

Discussion

The results of this study show that the Nd-YAG laser provided immediate palliative relief in four symptomatic patients with severe tracheal stenosis associated with life-

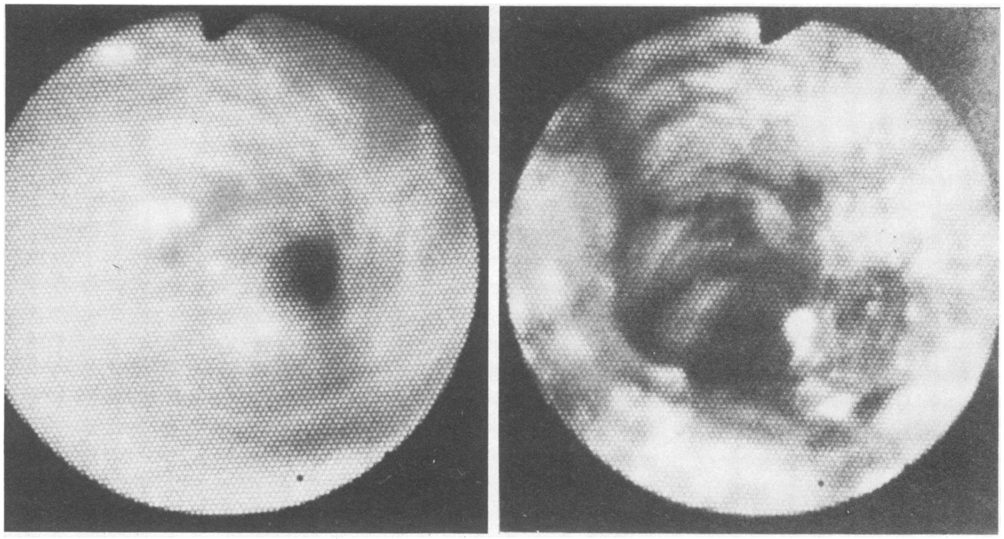

Figure 2.—Tracheal stenosis in patient 3 before (left) and immediately after (right) laser therapy. Diameter was increased from 2.5 to 10 mm.

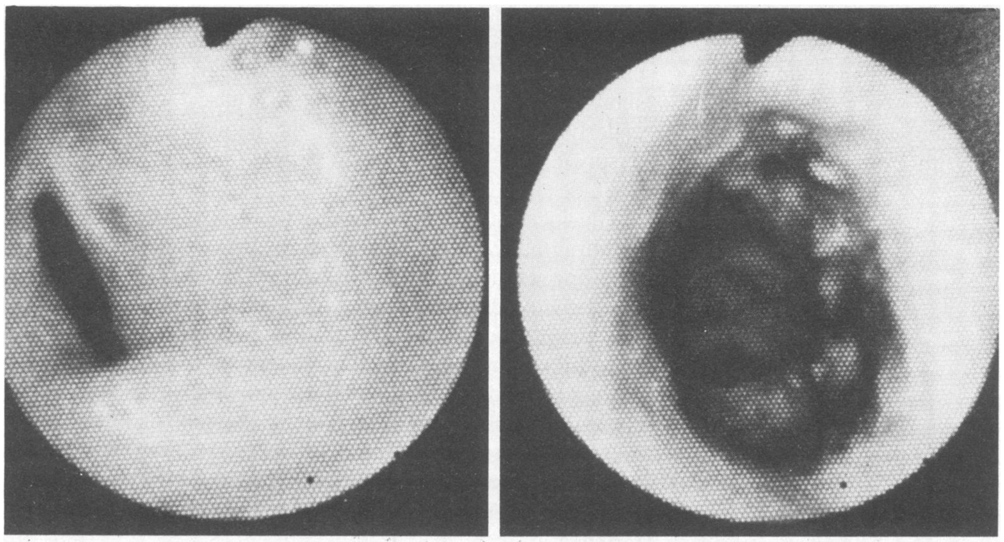

Figure 3.—Tracheal stenosis in patient 4 before (left) and immediately after (right) laser therapy. Diameter was increased from 5 to 11 mm.

threatening cough, stridor or dyspnea. Furthermore, there existed no rational alternative therapy as previous attempts at mechanical dilatation had failed and the stenosis was felt to be too advanced for surgical excision in these already compromised patients. The diagnostic decision to consider superimposed tracheal stenosis in a patient already dyspneic and compromised by chronic cardiac or respiratory failure or both is difficult. However, it should be considered in the setting of previous endotracheal intubation or tracheostomy, especially with the development of an inspiratory stridor or unexplained cough. While the results of pulmonary function studies in these patients are often abnormal, the development of low-flow plateaus on the maximal inspiratory or expiratory flow volume loops may suggest intrathoracic or extrathoracic tracheal stenosis.[7] The diagnosis can only be confirmed by bronchoscopy, but a chest roentgenogram or tracheal tomography may be helpful.

The treatment of tracheal stenosis is complex and challenging. Usually, in milder instances mechanical dilatation with rigid bronchoscopy may suffice, whereas in more advanced stages, excision of stenotic areas followed by reconstruction may be required. Most recently, endoscopic methods using carbon dioxide and Nd-YAG lasers have provided therapeutic alternatives to traditional surgical methods.

Tracheal stenosis from endotracheal intubations or tracheostomy may result in various complications. Least troublesome are localized granulomas, though at times they may reach considerable proportions. More troublesome is the outgrowth of a fibrous web or diaphragm. Moreover, the fibrous tissue may extend longitudinally to involve more of the trachea. The most complicated variant includes involvement of the tracheal wall itself with erosion and possible fracture of the cartilaginous rings and collapse.

In the present study all of the patients had either a diaphragmatic web or longitudinally extended stenosis that spared the tracheal wall itself, allowing it to maintain its stability. This type of stenosis should be most responsive to cure by laser therapy.[8,9] For cases of more advanced tracheal stenosis including collapse, Toty and co-workers[8] reported that after a 6- to 18-month follow-up, 8 of 17 patients treated with the Nd-YAG laser required additional surgical reconstruction. An incidence of only 50% improvement was also noted by Dumon and associates[9] using the Nd-YAG laser and

33% by Simpson and colleagues[10] using the carbon dioxide laser in six cases. Selected patients may ultimately require a Montgomery tube for stabilization or sleeve resection.

Whereas there were no complications in the present laser series, it would be anticipated that complications could occur, similar to those in laser treatment of endobronchial tumors.[1,8,9,11-14] It is too early to compare the effectiveness of the carbon dioxide and Nd-YAG laser techniques. Toty and co-workers[8] and Dumon and associates[9] developed the pioneering techniques that allowed Nd-YAG laser bronchoscopy to clinically mature. They both favor the use of the rigid bronchoscope to deliver the laser fiber and to provide better access. The drawback, however, is the need for deeper anesthesia, which may result in further respiratory compromise. Brutinel and colleagues[13] have documented the deterioration of gas exchange during laser therapy. While the fiberoptic bronchoscope may be adequate in many cases, the rigid bronchoscope is necessary and mandatory to remove large pieces of coagulated tissue that are obstructing the trachea. We favor the use of both fiberoptic and rigid bronchoscopy with intravenously administered sedatives and the patients breathing on their own.

Finally, we must consider the issue of the clinical justification of this relatively expensive procedure. It appears to offer excellent palliative relief in patients with tracheal stenosis with life-threatening dyspnea, cough or stridor who have severe air-flow limitation, cases for which there currently exists no other medical alternative. Optimal results may ultimately require additional surgical procedures but the initial goal is to provide an adequately patent trachea for ventilation. The use of the laser for the treatment of benign tracheal stenosis complements its established use in treating endobronchial malignant tumors.[1,8,9,11-14] Furthermore, the cost of laser treatment is far less than the accumulative cost of a lengthy hospital stay for an asphyxiating patient for whom no other reasonable therapeutic alternative exists.

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